This invention relates to a sound generator for producing high intensity sounds in the sonic and ultrasonic frequency range. The invention can be used in any application involving high intensity sounds, but it is particularly useful in the deforming, degassing, mixing, or air-free agitation of fluids such as shampoos, detergents, pharmaceuticals, polymers and paper chemicals, food products, beer or the like.

In the manufacture and processing of the above noted fluids it is necessary to remove heavy layers of foam which accumulate on top of the fluids and to mix or agitate the fluids in such a way as to produce a minimum of foam. It has been found in the prior art that high intensity sound is an effective deforming agent, and high intensity sound generators have accordingly been devised for this purpose as described, for example, in an article entitled “Sound Breaks the Foam Barrier,” which appeared in the May 6, 1961, issue of Chemical Week on pages 51 and 52. This article discusses the physical principles involved in the deforming of fluids by sound waves and describes several high intensity sound generators which are representative of the prior art. These sound generators differ somewhat in their specific details, but they are all based on a whistle principle of operation, i.e., they generate sound waves by interrupting a stream of moving air in one way or another. Although these prior art sound generators have proven workable in practice, they suffer from several serious drawbacks which are inherent in the whistle principle of operation. In the first place, they cannot be used in sealed tanks because they must continuously emit a jet of air in order to produce a sound. Secondly, to produce a high intensity sound these whistles require vibrating parts, which are subject to clogging when used in a foam filled atmosphere. One of these prior art generators has eliminated moving parts by using a resonant air chamber, but this particular generator still requires a continuous stream of air and it is quite inefficient in operation. Furthermore, none of these prior art sound generators can be immersed in a fluid, which means that they can only be used in defoaming and are entirely useless in the closely related problems of degassing, mixing, and air-free agitation of fluids. In addition, it is not possible to produce arbitrary, predetermined frequency amplitude characteristics by the whistle principle of operation, and it is difficult to change or adjust the output characteristics of a whistle sound generator.

Accordingly, one object of this invention is to provide a high intensity sound generator which is simpler in structure, more reliable in operation, and more efficient than those herefore known in the art. Another object of this invention is to provide a high intensity sound generator which can be used in a sealed atmosphere or in a fluid.

A further object of this invention is to provide a high intensity sound generator for producing sound waves having any desired frequency/amplitude characteristics.

An additional object of this invention is to provide a high intensity sound generator in which the sound wave output can be quickly and easily changed from one frequency/amplitude characteristic to another.

Other objects and advantages of this invention will be apparent to those skilled in the art from the following description of one specific embodiment thereof, as illustrated in the attached drawings, in which:

FIG. 1 is a perspective view of one illustrative embodiment of this invention;
FIG. 2 is an enlarged axial section of the embodiment shown in FIG. 1;
FIG. 3 is an elevation view partly in section on a reduced scale of a fluid tank with the embodiment of FIG. 1 mounted in the top of the tank for defoaming liquid therein; and
FIG. 4 is an elevation view partly in section on a reduced scale of a fluid tank with the embodiment of FIG. 1 mounted in the bottom of the tank for air-free agitation of liquid therein.

The sound generator for this invention avoids the drawbacks of the prior art sound generators by utilizing the tuning fork principle of operation instead of the whistle principle of operation. In accordance with the most fundamental aspect of this invention, high intensity sound is generated by mechanically exciting an acoustically resonant antenna element whose dimensions and physical characteristics are chosen to produce an output sound of predetermined amplitude/frequency characteristics. In accordance with a further aspect of this invention, an acoustic antenna array is formed by mounting a plurality of acoustically resonant antenna elements at nodal points on a supporting member, which is excited by an automatic hammer working against one end thereof. The hammer sends mechanical shock waves down the supporting member, and these shock waves are reflected back and forth from the ends of the supporting member to define nodal points at which the shock waves can be coupled out of the supporting member to generate an output sound of the maximum amplitude at the nodal points. The acoustically resonant elements are located at these nodal points, they are excited by the shock waves in a very efficient manner and produce sonic or ultrasonic output waves by vibrating at their natural resonant frequency. The output sound from this antenna array is, of course, the composite of the output sounds from the individual acoustically resonant elements.

FIGS. 1 and 2 show one illustrative embodiment of the invention which is adapted to be mounted in a fixed position by means of a supporting collar 10. An air hammer assembly 12 is rigidly attached to one side of the tank 14 and an acoustic antenna assembly 14 projects from the other side thereof. The periphery of collar 10 is drilled to accept bolts or machine screws so that the sound generator can be mounted in a fluid tank or the like, as shown in FIGS. 3 and 4.

In this particular embodiment of the invention, the acoustic antenna assembly contains a hollow supporting member 16 which is attached at one end to an anvil member 18 by means of screw threads 16' as shown in FIG. 2. Supporting member 16 is held in axial alignment with collar 10 by a base plate 20, which is secured to collar 10 by machine screws 20'. Supporting member 16 slides through a central opening cut into collar 10 and base plate 20 and is secured against longitudinal movement by a nut 22, which bears against the bottom of collar 10 via a series of spacers 21. A plurality of resonant discs R1 . . . R5 are secured at predetermined points along supporting member 16 by spacers S1 . . . S5. It will be apparent to those skilled in the art that nut 22 simultaneously serves to secure the resonant discs R1 . . . R5 to supporting member 16 and also to secure supporting member 16 to collar 10.

The acoustic antenna array is excited by periodic blows from a pneumatic hammer 23 which is mounted within a cylindrical case member 24 in such position as to work against anvil member 18. Case member 24 is secured to collar 10 by machine screws, as shown in FIG. 2, and air is conveyed to hammer 23 through air conduit 27. Exhaust air is released from pneumatic hammer 23 from an exhaust port which is not shown in
the drawings, but whose location and operation will be apparent to those skilled in the art. The particular embodiment shown in FIGS. 1 and 2 is designed to utilize a 3,160,138 1 pneumatic type air hammer, such as manufactured by the Cleveland Vibrator Company of Cleveland, Ohio, but it will be apparent to those skilled in the art that any suitable pneumatic hammer can be used in connection with this invention. It will also be apparent that an electric hammer could also be used, if desired, but that a pneumatic hammer is preferable if the noise generator is to be used around inflammable liquids or in an explosive atmosphere.

The speed of frequency of air hammer 22 is an important factor because it determines the position of nodal points on the acoustic antenna array. Each time the hammer strikes anvil 18 it sends a shock wave down supporting member 16. This shock wave travels at a speed which is determined by the physical characteristics of supporting member 16, and when it reaches the end of the member, it is reflected back toward anvil 18. On its return trip the shock wave meets other shock waves generated by subsequent blows of the hammer, and these shock waves reinforce each other at nodal points which are determined by the length of supporting member 16, the velocity of the shock waves therein, and the frequency of the hammer blows. In general, the nodal points will be half-wavelength points on the supporting member where the wavelength \( \lambda \) is computed from the formula \( \lambda = \frac{V}{F} \), where \( V \) is the speed of propagation and \( F \) is the frequency of the hammer blows. To get the most efficient transfer of mechanical energy from the supporting member to the resonant disc it is necessary to place the discs on or very close to these nodal points. Therefore, the hammer frequency will determine the spacing of the resonant discs or vice versa, depending on which is chosen first. In some cases the spacing will be determined by spatial limitations, in which case the hammer frequency will be determined by the spacing, but in very high intensity sound generators the hammer frequency will more likely be the controlling factor.

Although the approximate location of the nodal points can be calculated in advance for any specific embodiment of the invention, it is preferable to verify their exact location by measurement and to correct spaces S1 . . . S5 to compensate for any deviation between the theoretical nodal points and the actual nodal points. It is also preferable to make the central hole in the resonant discs slightly undersize to insure good mechanical coupling between the supporting member and the resonant discs. This acoustical antenna array is very efficient when the resonant discs are properly spaced and snugly coupled to the supporting member. If the energy from the shock wave is not absorbed by the resonant discs on the first round trip, the remainder of the energy will be reflected back from anvil, and it will bounce back and forth along the supporting member until it is completely absorbed. Since most metals are highly elastic, the propagation losses are quite low and most of the energy goes into the resonator.

The output characteristics of the sound generator are, of course, determined by the physical characteristics of the resonant discs, which can be formed so as to produce any desired frequency or spectrum of frequencies in the sonic or ultrasonic range. It should be noted, though, that the output frequency is independent of the hammer frequency; like a tuning fork, the acoustic antenna array will always produce the same output sound regardless of how fast or how slowly it is struck by the hammer. The output sound can be focussed or spread out as desired by mounting a suitable directional acoustic reflector on the forward side of collar 19, but this is not essential in basic operation of the invention. It might, however, be preferable to use suitable reflectors in some embodiments of the invention.

The output sound can be a narrow band of frequencies if desired, in which case all of the resonant discs will be the same, or it can be a broad band of frequencies, in which case the individual resonant discs will vary in diameter, thickness, or material, as will be readily understood by those skilled in the art. The particular embodiment shown in FIGS. 1 and 2 is adapted to produce a moderately broad band of frequencies by using discs of slightly different diameter. The same effect could be obtained, however, by varying the width or the material of the discs in diameter.

FIGS. 3 and 4 show two illustrative applications of the above described embodiment of the invention. As shown in FIG. 3, this embodiment can be mounted in the top of a fluid tank 36 for defoaming the fluid 32 therein. It can also be mounted in the bottom of a fluid tank 39 (FIG. 4) for degassing, mixing, or air-free agitation of the fluid 32 therein. These two applications are very important, but they are by no means exhaustive of the uses for this particular embodiment of the invention. It can also be used for environmental testing of electronic components, for pumping fluids, for repelling birds, mice, or other pests, and in many other applications where high intensity sound is useful.

This particular embodiment of the invention can be adapted to produce output frequencies from 10 kilocycles to 100 kilocycles at sound levels as high as 150 decibels. The output frequency and frequencies can be quickly changed by removing nut 22 and replacing the resonant discs or the resonator discs on the antenna array with different resonant discs. Any suitable metal can be used for the various parts of the structure, but in most cases it will be preferable to use a non-corrosive metal such as stainless steel or the like. If desired, a handle can be added to the air gun assembly to adapt this embodiment for portable use. In this case it may be desirable to shorten the acoustic antenna assembly and to use only one or two resonant discs. One portable embodiment of this type has been found to be very useful for mixing paint in small cans.

From the foregoing description it will be apparent that this invention provides a high intensity sound generator which is simpler in structure, more reliable in operation, and more efficient than those heretofore known in the art. It will also be apparent that this invention provides a high intensity sound generator which can be used in a sealed atmosphere or in a fluid, and which can be easily adapted to produce sound waves having any desired frequency/amplitude characteristics. And it should be understood that this invention is by no means limited to the specific structure disclosed herein by way of example, since many modifications can be made in the structure departing from the basic teaching of this invention. For example, although the resonant discs are shown to be removable attached to their supporting member, they could just as well be permanently attached thereto if desired. The removable connection has the advantage of changeability, but a permanent attachment might be desirable in fixed frequency installations to strengthen the antenna array and increase its efficiency. In addition, a solid supporting member could be used in place of the hollow supporting member shown, and some of the resonant discs might be displaced from their nodal points to mute one or more frequencies in the composite output sound. When a disc is displaced from its nodal point it will receive less energy than the other discs in proportion to the amount of displacement. Therefore it will vibrate at a correspondingly lower amplitude and produce a lower intensity output sound. Furthermore, there are other mechanical mechanical arrangements which can be used to secure the acoustic antenna of this invention to the automatic hammer thereof, and many other mechanical configurations for embodying the acoustic antenna of this invention. These and many other applications disclosed structure will be apparent to those skilled in the art, and this invention includes all modifications falling within the scope of the following claims.
I claim:

1. A sound generator comprising acoustically resonant antenna means and automatic hammer means adapted to periodically strike said antenna means to produce vibrations therein at the resonant frequency thereof.

2. A sound generator comprising antenna means having substantially flat antenna elements, said antenna elements being attached transversely to a supporting rod and being adapted to vibrate at a predetermined resonant frequency in response to shock waves transmitted down said supporting rod, automatic hammer means adapted to periodically strike one end of said supporting rod at a predetermined frequency to send longitudinal shock waves down said rod, the frequency of said automatic hammer means being of such value as to produce a shock wave node on said supporting rod at its point of attachment to said antenna elements, thereby causing said antenna means to vibrate with maximum amplitude at the resonant frequency thereof.

3. A sound generator comprising antenna means having spaced substantially flat antenna elements, said antenna elements being attached transversely to a supporting rod and being adapted to vibrate at a predetermined resonant frequency in response to shock waves transmitted down said supporting rod, automatic hammer means adapted to periodically strike one end of said supporting rod at a predetermined frequency to send longitudinal shock waves down said rod, the frequency of said automatic hammer means being of such value as to produce a shock wave node on said supporting rod at its point of attachment to said antenna elements, thereby causing said antenna means to vibrate with maximum amplitude at the resonant frequency thereof.

4. A sound generator comprising a plurality of resonant discs each having a central opening formed therein, each of said resonant discs being adapted to vibrate at a predetermined resonant frequency when struck by a mechanical shock wave, an antenna supporting rod adapted to transmit mechanical shock waves along the longitudinal dimension thereof, automatic hammer means adapted to periodically strike one end of said supporting rod to send longitudinal shock waves down said rod, said rod being adapted to reflect said shock waves back from the other end thereof to produce nodal points along said rod, and means for removably securing each of said resonant discs to a corresponding nodal point on said rod whereby each of said discs receive said shock waves and are caused to vibrate with maximum amplitude at the corresponding resonant frequency thereof.

5. A sound generator comprising a plurality of substantially flat antenna elements, each of said antenna elements being adapted to vibrate at a corresponding resonant frequency when struck by a mechanical shock wave, an antenna supporting rod adapted to transmit mechanical shock waves along the longitudinal dimension thereof, automatic hammer means adapted to periodically strike one end of said supporting rod to send longitudinal shock waves down said rod, said rod being adapted to reflect said shock waves from the other end thereof to produce shock wave nodal points on said rod, and each of said antenna elements being attached transversely to said supporting rod at a corresponding nodal point theron, whereby each of said antenna elements receive said shock waves and are caused to vibrate with maximum amplitude at the corresponding resonant frequency thereof.

6. A sound generator comprising a plurality of resonant discs each having a central opening formed therein, each of said resonant discs being adapted to vibrate at a predetermined resonant frequency when struck by a mechanical shock wave at the periphery of said central opening therein, a supporting rod adapted to be inserted snugly through said central openings of said resonant discs, said supporting rod being adapted to transmit mechanical shock waves along the longitudinal dimension thereof, automatic hammer means adapted to periodically strike one end of said supporting rod to send longitudinal shock waves down said rod, said rod being adapted to reflect said shock waves back from the other end thereof to produce nodal points along said rod, and means for removably securing each of said resonant discs to a corresponding nodal point on said rod whereby each of said discs receive said shock waves and are caused to vibrate with maximum amplitude at the corresponding resonant frequency thereof.

7. A sound generator comprising an acoustically resonant antenna array consisting of a longitudinal supporting member having a plurality of resonant discs projecting radially from said supporting member at spaced points therealong, automatic hammer means adapted to periodically strike one end of said supporting member to produce longitudinal shock waves therealong, and each of said resonant discs being adapted to vibrate at a corresponding resonant frequency when struck by said shock waves.

8. A sound generator comprising acoustically resonant antenna means consisting of a longitudinal supporting member having a resonant disc member projecting radially from one end thereof, automatic hammer means adapted to periodically strike the other end of said supporting member to produce longitudinal shock waves therealong, and said resonant disc member being adapted to vibrate at a predetermined resonant frequency when struck by said shock waves.

9. A process for producing high intensity sound waves comprising the steps of periodically striking an acoustically resonant antenna at the resonant frequency thereof.

10. A process for producing high intensity sound waves comprising the steps of periodically striking an acoustically resonant antenna of the type having equally spaced disc like elements substantially spaced on a common support, at a frequency having a corresponding wavelength substantially equal to twice the distance between said disc like elements.

11. The sound generator of claim 7 in which said discs are of equal diameter.

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